National Renewable Energy Laboratory
Innovation for Our Energy Future

Low Energy Building and Campus Design

NASA 2010 International Workshop on Environment and Alternative Energy

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November 2, 2010

Sustainability principles for NREL's campus build-out

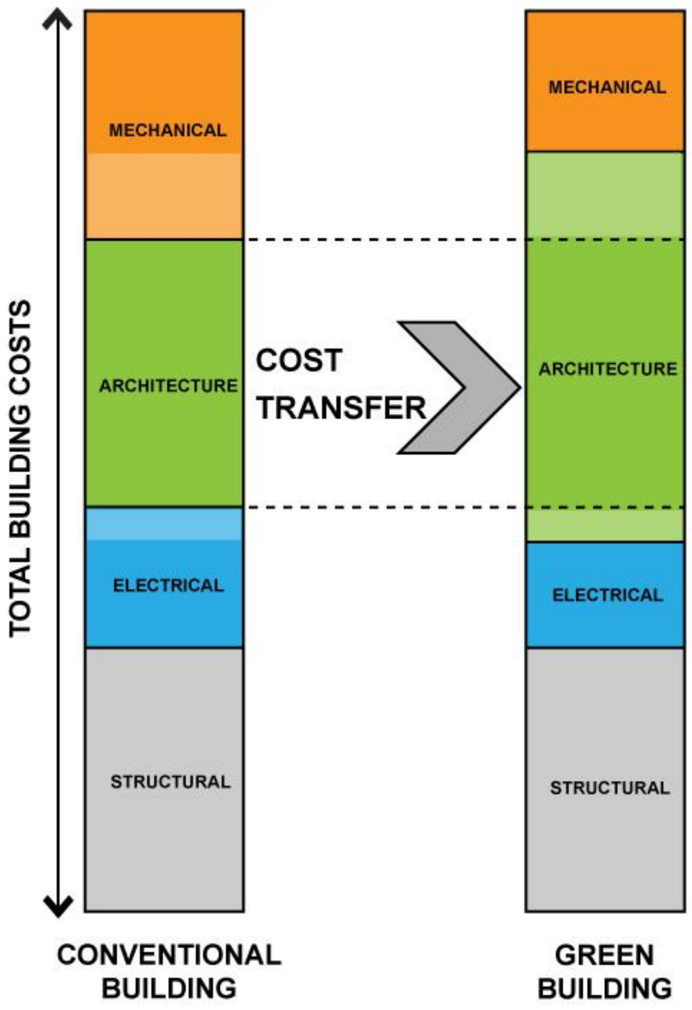
- Campus to reflect our mission/sustainable values
- Consolidate staff on the STM campus
- Preserve the natural environment
- Enhance DOE & NREL's visibility with the public
- Consolidate parking and use alternative transportation
- Improve pedestrian circulation
- More indoor and outdoor informal gathering spaces
- A more cohesive/integrated look

"Our research is so important, but I'm afraid that it will not bring us half the notoriety as a cutting edge, environmentally sound, high performing campus. That may be the best teaching and outreach campus we can offer the public"

Integrated Design

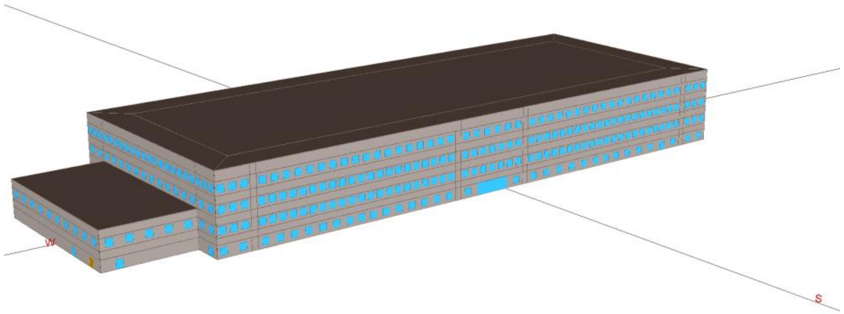
Cost Transfer

Transfer costs from mechanical and electrical systems to building architecture



Integrated Design

Design Simulations



Credit: EMC Engineers

- Energy modeling
- Daylight modeling
- Natural ventilation modeling
- Thermal mass modeling

- **And all must meet the Cost Model**

Research Support Facility

Completed 6/2010 – moving in
Planned for 800 employees
Has a defined energy goal (35 KBTU\SF\yr)
Requirement of LEED Platinum
NREL Business data center

Computer rendering of the RSF






Research Support Facility

“Raise the national standard for high-performance commercial buildings and effectively transfer this knowledge to other
- DOE Expectations letter

- **Create a “national showcase” -**
  - demonstrate how high-performance buildings can be aesthetically compelling, acquired at competitive first-cost and life-cycle cost, and through integrated design, can reduce performance risks to the owner, constructor and financier

Problem Definition – Proposal Objectives Checklist

<u>MISSION CRITICAL</u>

Attain safe work performance/Safe Design Practices

LEED Platinum

Energy Star "Plus"

<u>HIGHLY DESIRABLE</u>

800 staff Capacity

25kBTU/sf/year

Architectural integrity

Honor future staff needs

Measurable ASHRAE 90.1

Support culture and amenities

Expandable building

Ergonomics

Flexible workspace

Support future technologies

Documentation to produce a "How to" manual

"PR" campaign implemented in real-time

Allow secure collaboration with outsiders

Building information modeling

Substantial Completion by 2010

<u>IF POSSIBLE</u>

Net Zero/design approach

Most energy efficient building in the world

LEED Platinum Plus

ASHRAE 90.1 + 50%

Visual displays of current energy efficiency

Support public tours

Achieve national and global recognition and awards

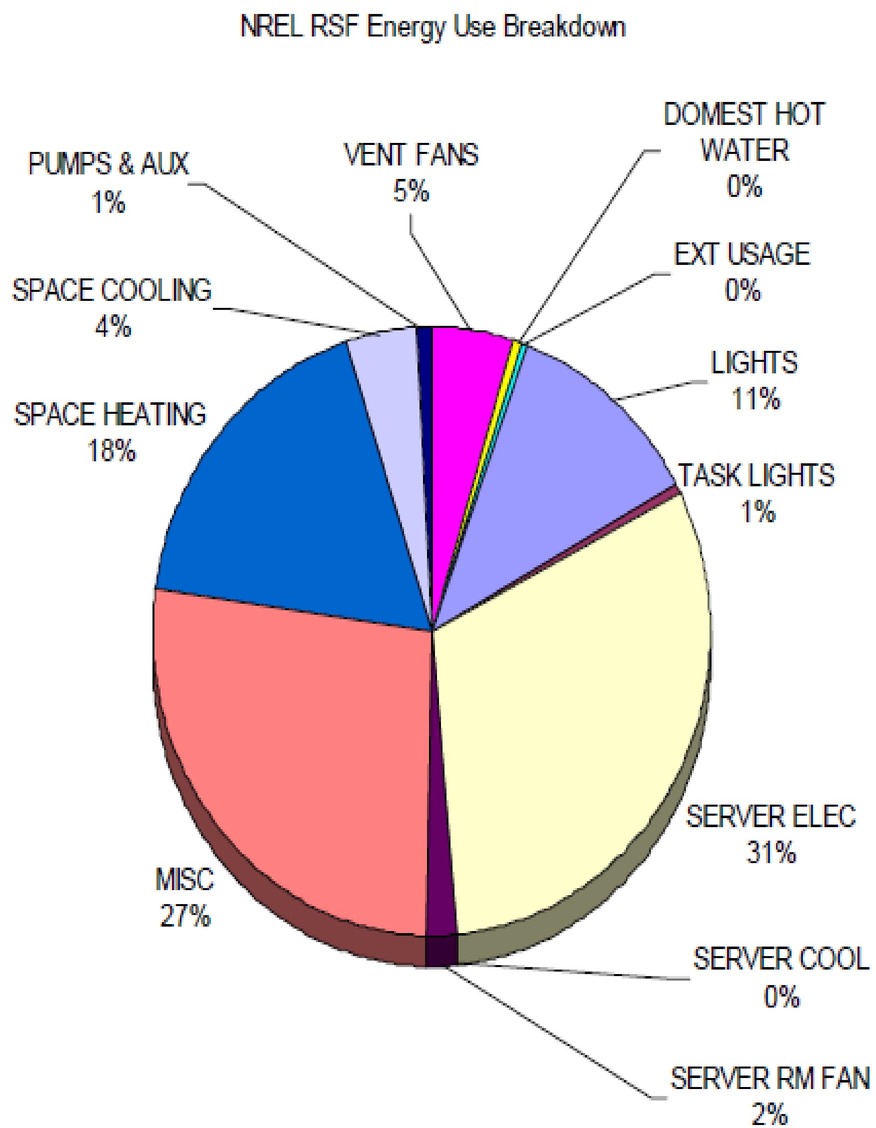
Support personnel turnover

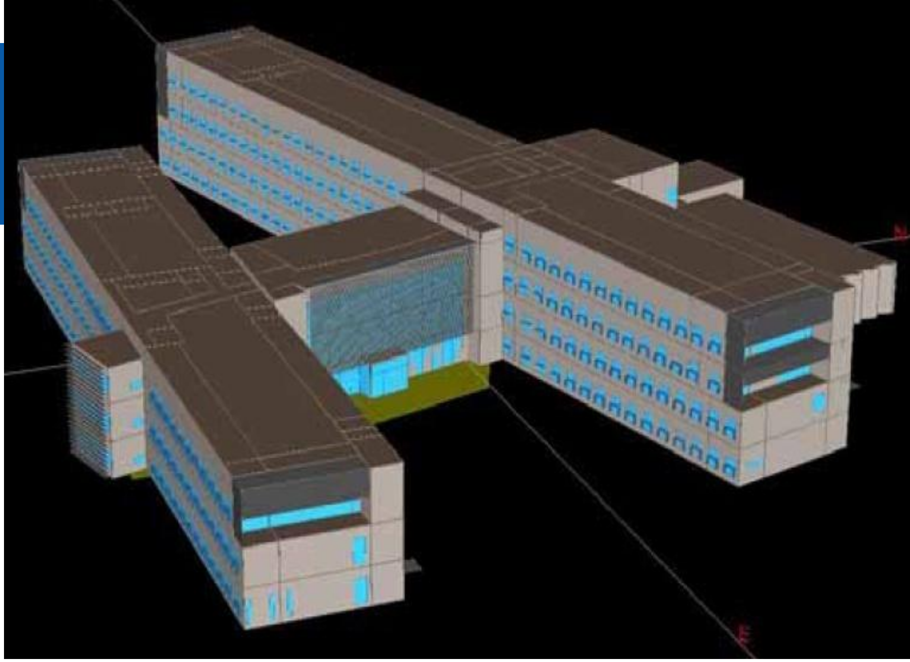
RSF: Problem Statement

- 800 people
- 220,000 ft^2
- 35 $kBtu/ft^2$
- LEED Platinum +
- 50% energy savings
- $259/ft²
- Replicable
    - process
    - technologies
    - cost
- Site, source, carbon, cost ZEB
    - Includes plug loads and datacenter

- Design/Build Process with required energy goals

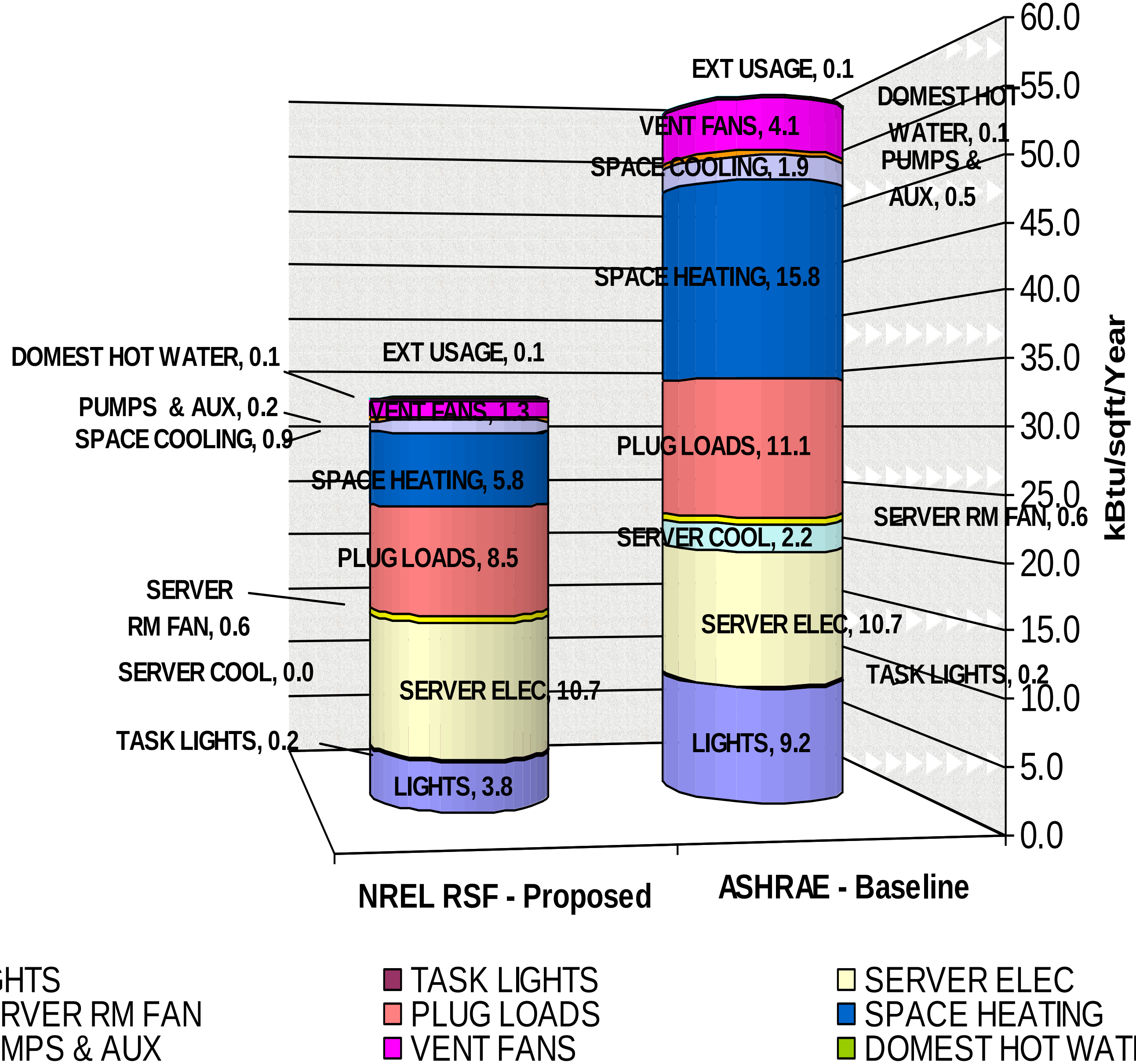
Energy Modeling



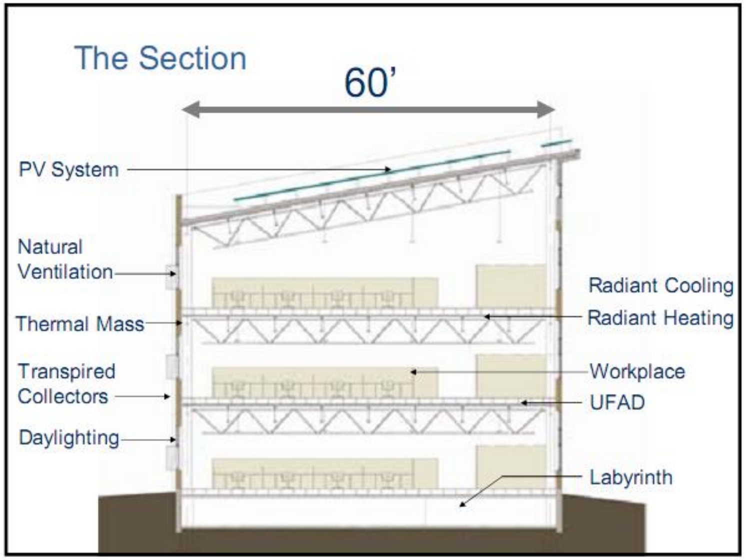


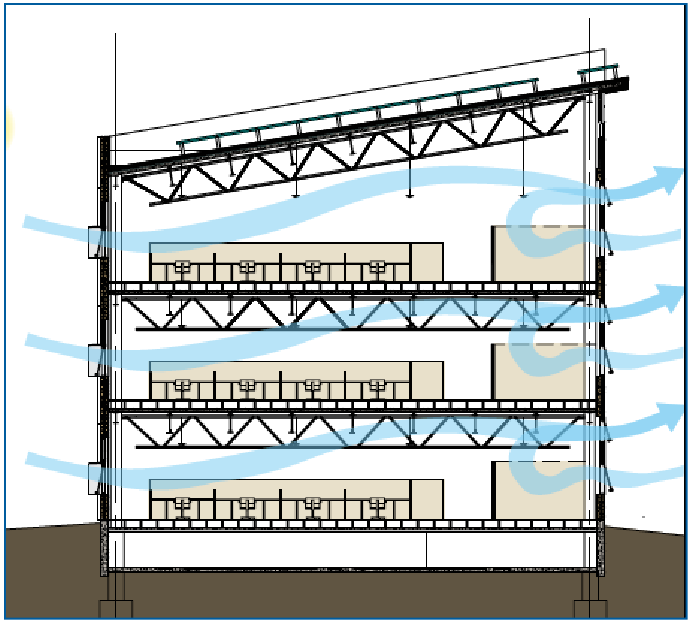
End Use	kBtu/ft2
Lights	3.85
Task Lights	0.19
Data Center	10.60
Data Center Cooling	0.01
Data Center Fans	0.55
Office Plug Loads	9.16
Space Heating	6.11
Space Cooling	1.42
Pumps	0.27
Ventilation Fans	1.61
Domestic Hot Water	0.13
Exterior Lights	0.12

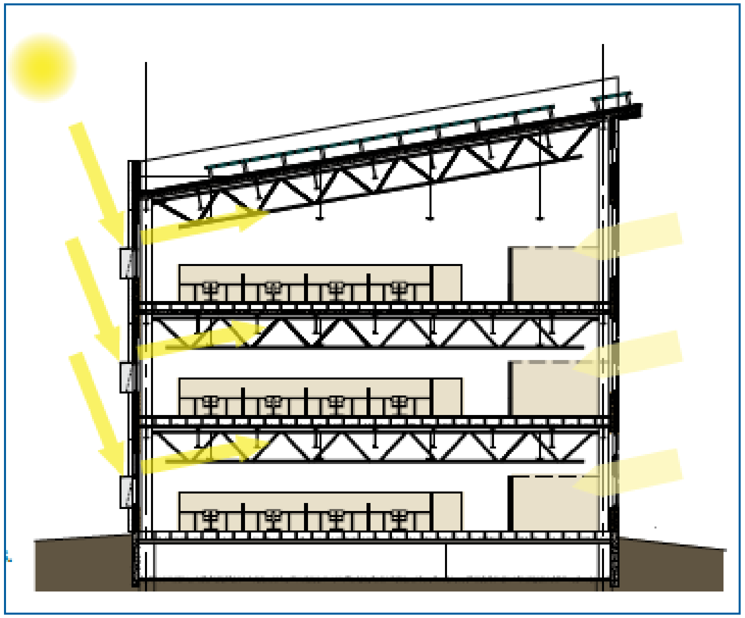
NREL RSF Annual Energy Consumption Comparison

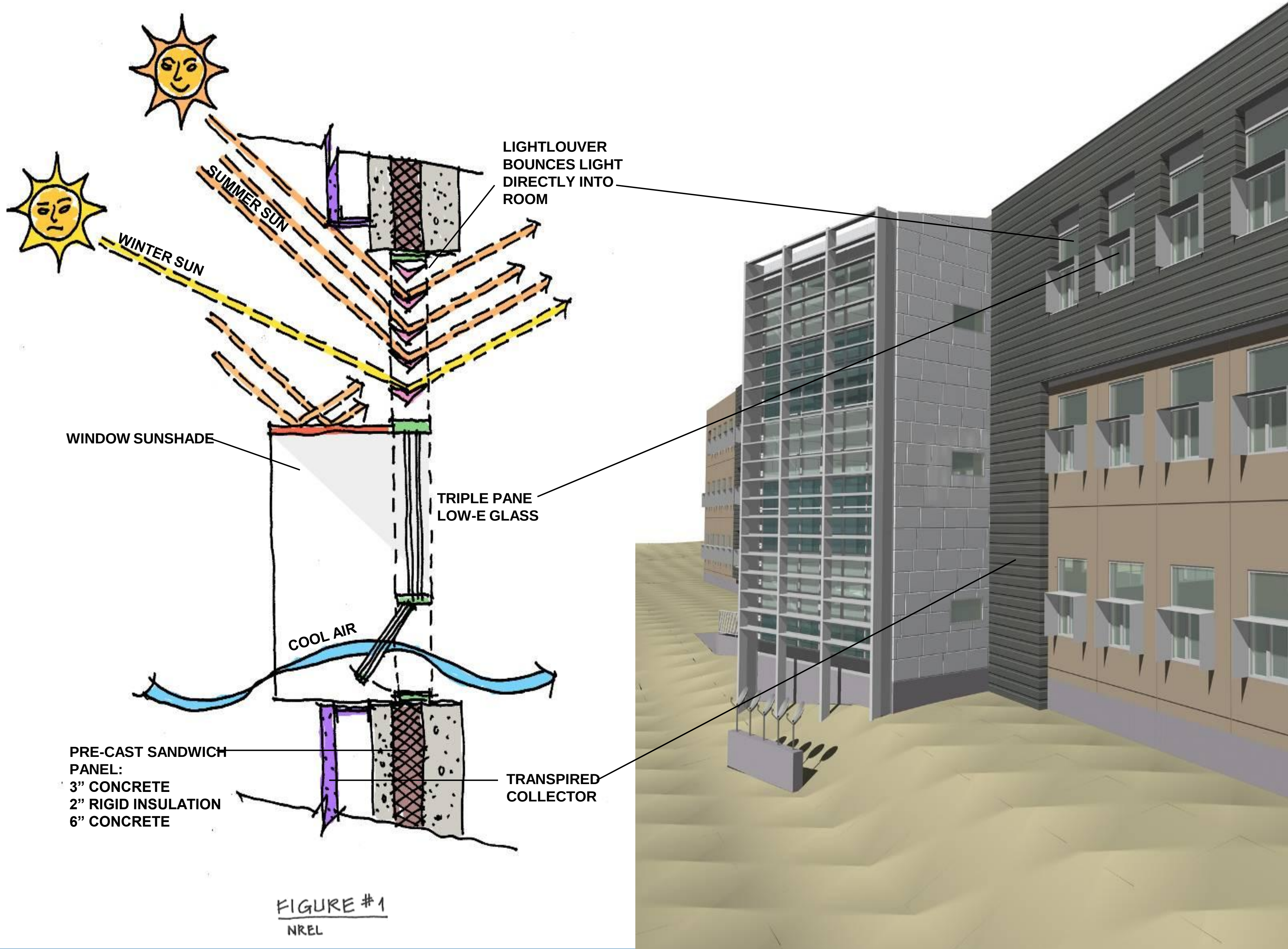


Open plan, narrow floor plate for natural lighting and ventilation



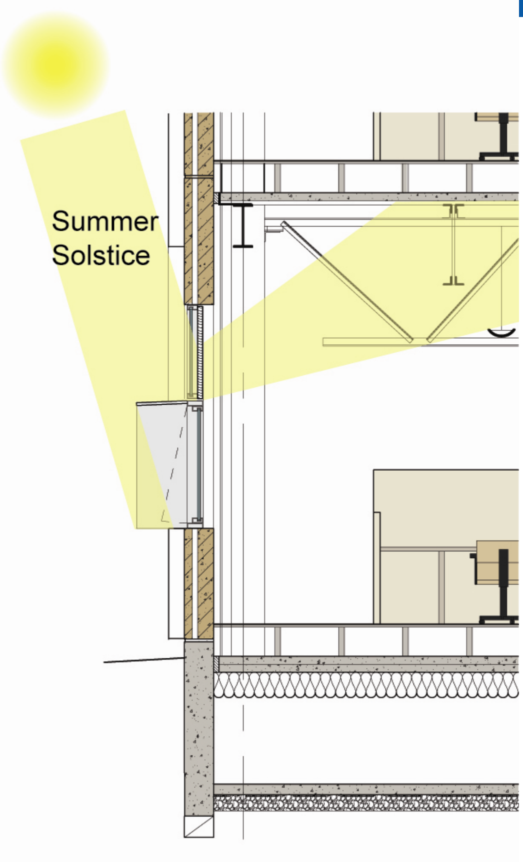






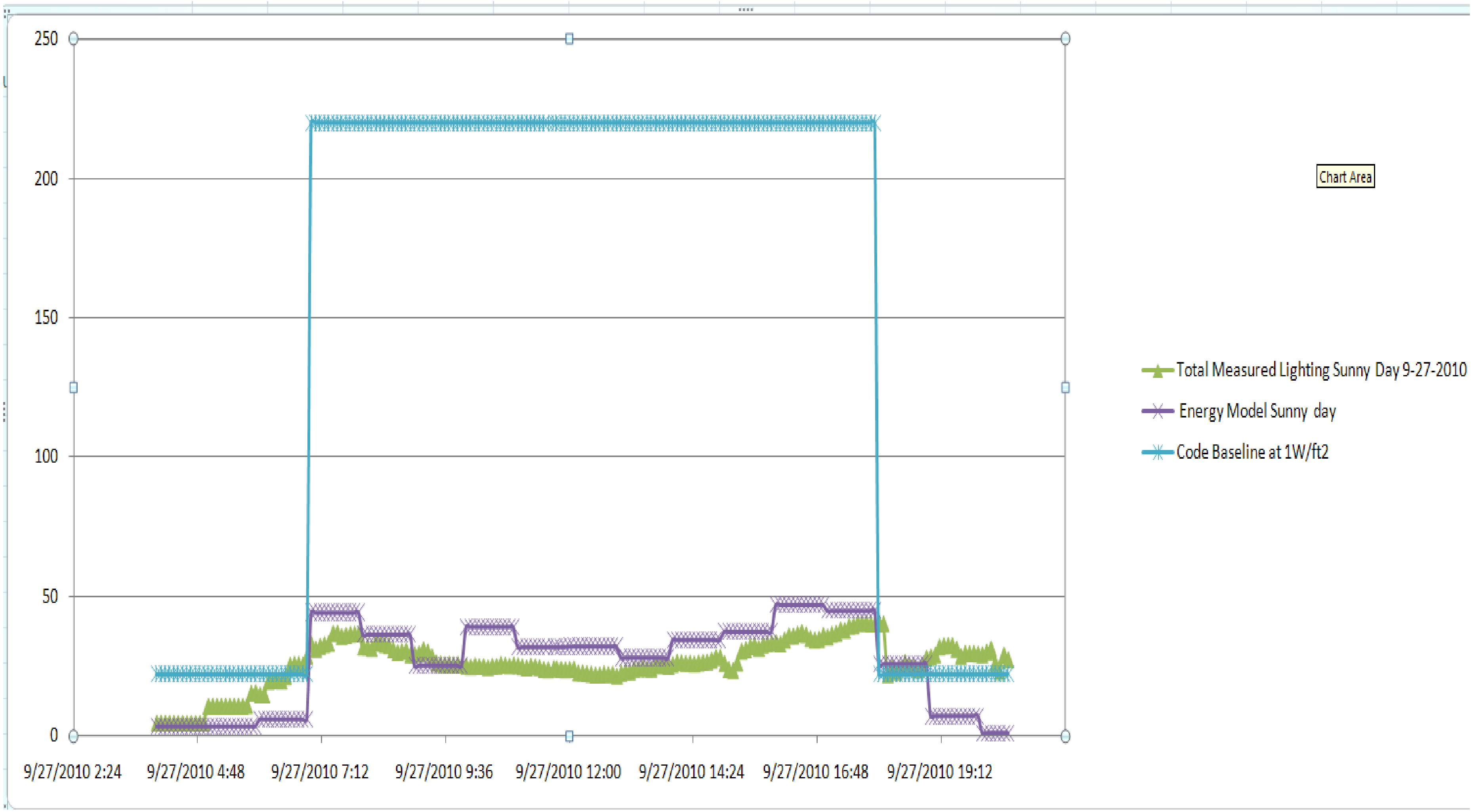
SUMMER SUN
WINTER SUN
LIGHTLOUVER BOUNCES LIGHT DIRECTLY INTO ROOM
WINDOW SUNSHADE
TRIPLE PANE LOW-E GLASS
COOL AIR
PRE-CAST SANDWICH PANEL:
3" CONCRETE
2" RIGID INSULATION
6" CONCRETE
TRANSPIRED COLLECTOR
FIGURE #1
NREL

Daylighting: Additional Considerations



- "Superior" daylight to all possible zones
  - Open and closed office, conference rooms, stairs, copy/break rooms, library, exercise, cafeteria, lobby
- Minimize HVAC obstructions
  - Don't want to block daylighting with overhead ductwork
  - Underfloor ventilation air
  - Radiant ceiling heating/cooling
- Orient steel decking ridges perpendicular to south/north orientation
  - minimize "light dams"
- High reflectance interiors
  - furniture, ceilings, walls, structure, etc
  - 90% plus acoustic panels

RSF Lighting Energy vs. Model



HVAC System

- DOAS underfloor in office areas
- Natural Ventilation in office, corridors, and conference rooms
- Radiant Heating and Cooling in offices with core and N/S zones
- VAV for conference rooms
- Campus Hot water and chilled water
    - Wood chip boiler 80% of hot water
    - High efficiency water cooled chillers
- Increased campus square footage by 60%, energy use by 6%
- 1,000 ft^2 per Ton of central plant cooling
    - typical 300-400 ft^2 /Ton

Radiant Heating and Cooling in Ceiling Slab

Best Practices Guide

Data Centers…

- Account for over 85MW of electrical power within DOE
- Continue to exhibit load growth
- Could account for 10 – 15 percent of Federal facility energy use
- Make up an estimated 15 percent of DOE's electric bill

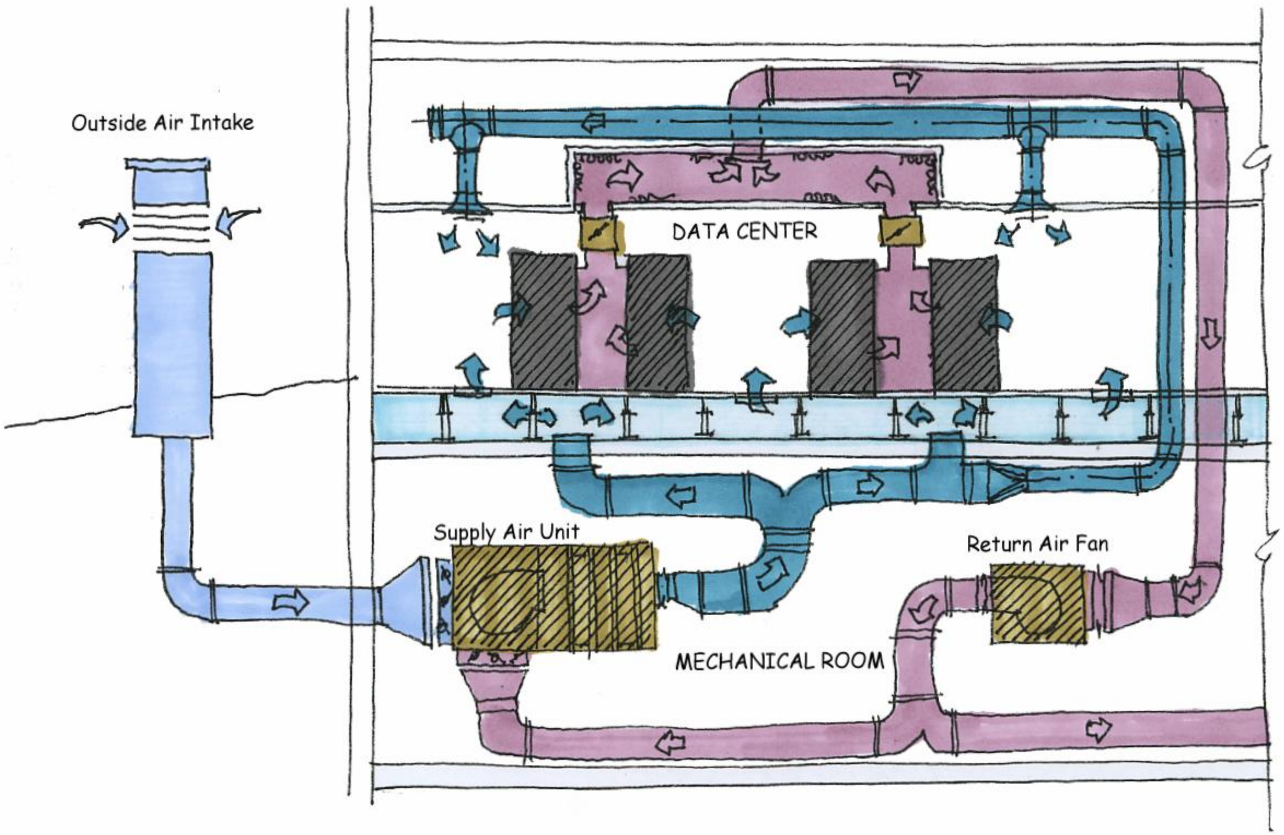
FEMP has compiled an overview of best practices for energy efficiency - much of which applies to HPC centers

http://www1.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf

BPG Table of Contents

1. **Summary**
2. **Background**
3. **Information Technology Systems**
   - Efficient Servers, Storage Devices, Network Equipment, Power Supplies, Consolidation (Hardware Location & Virtualization)
4. **Environmental Conditions**
5. **Air Management**
   - Cable Management, Aisle Separation & Containment, Supply & Return Air Configuration, Temperature Set Points
6. **Cooling Systems**
   - Direct Expansion (DX), Air Handlers, Chilled Water Systems, Free Cooling, Thermal Storage, Direct Liquid Cooling
7. **Electrical Systems**
   - Power Distribution, UPS, PDU, Distribution Voltage, Demand Response, DC Power, Lighting
8. **Other Opportunities for Energy Efficient Design**
   - On-Site Generation, Waste Heat
9. **Data Center Metrics & Benchmarking**

RSF Data Center



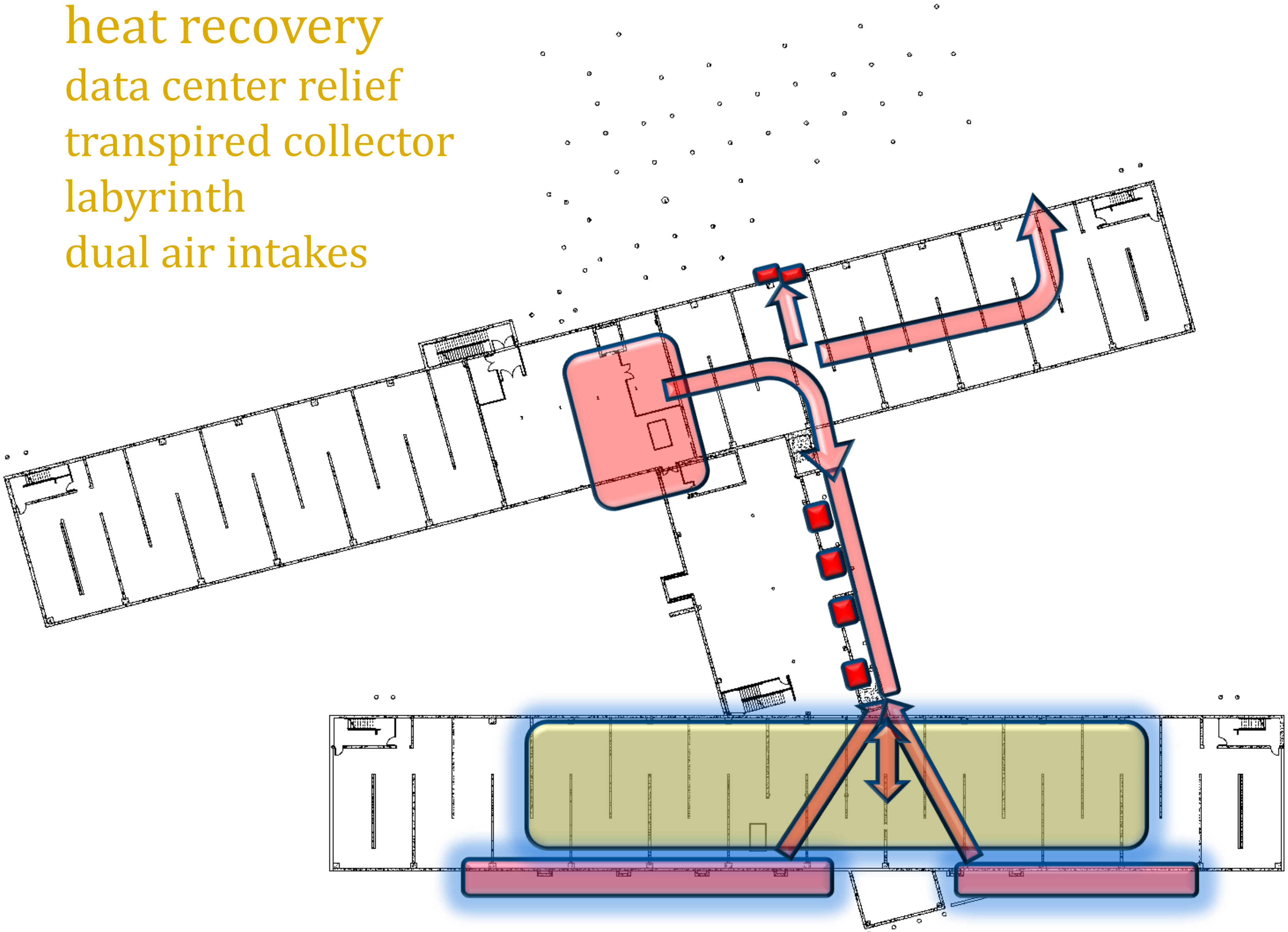
heat recovery

data center relief

transpired collector

labyrinth

dual air intakes



BASEMENT FLOOR PLAN

NREL RESEARCH SUPPORT FACILITY

RSF Data Center

RSF Plug Load Reduction Strategies

Elevators
- Use energy efficient traction elevators
- Change elevator lighting to energy efficient fluorescent lighting
- Turn off elevator lighting when the elevator is unoccupied

Break Rooms
- Increase the number of people that use each break room from approximately 20 to 30
- Eliminate the cooler on the drinking fountain

Task Lights
- Move from 35W fluorescent task lights to 6.2W LED task lights

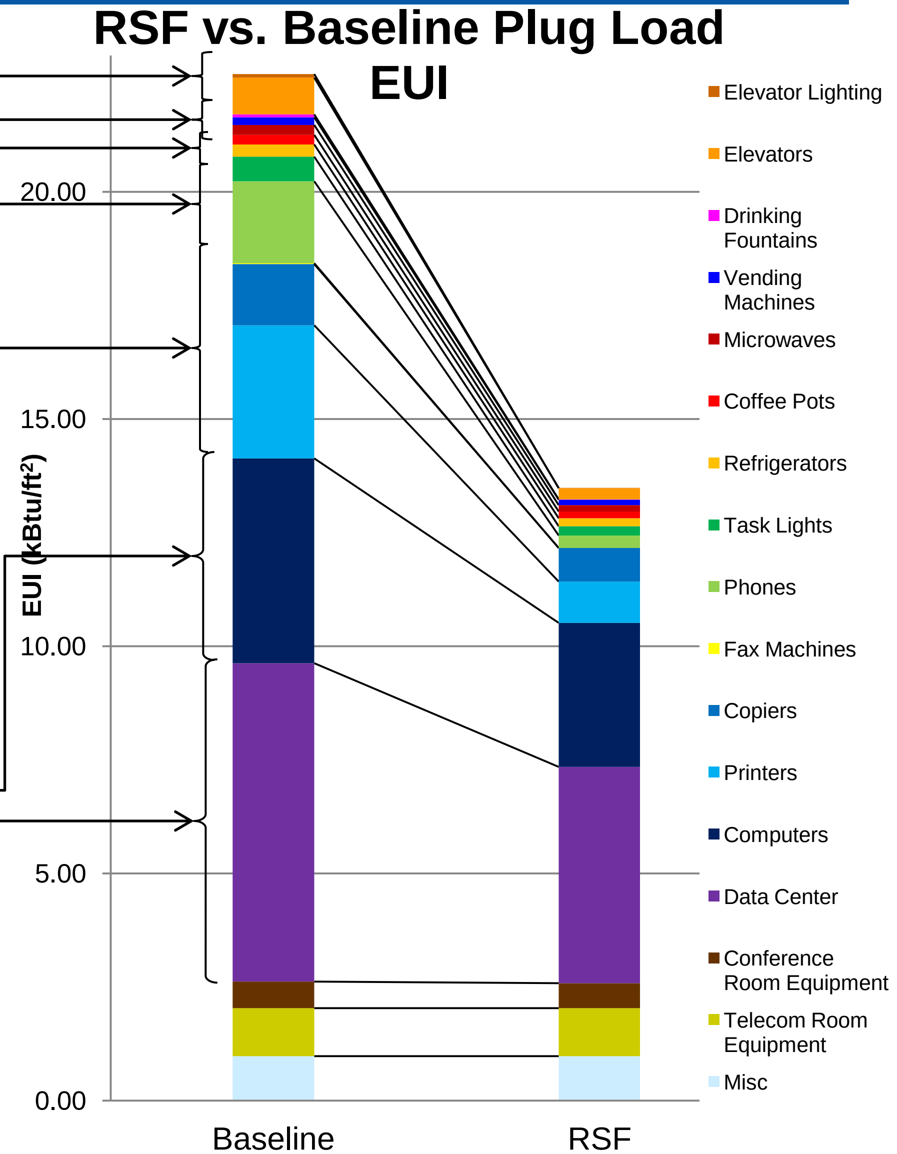
Phones
- Go from 1000 standard phones to 1000 VOIP phone that consumes 2W each

Copiers, Printers, Fax Machines
- Decrease the number people that use individual copiers, printers and fax machines
- Increase the number of people that use common, or group, copiers, printers and fax machines from 15 to 20
- Increase the use of all-in-one machines

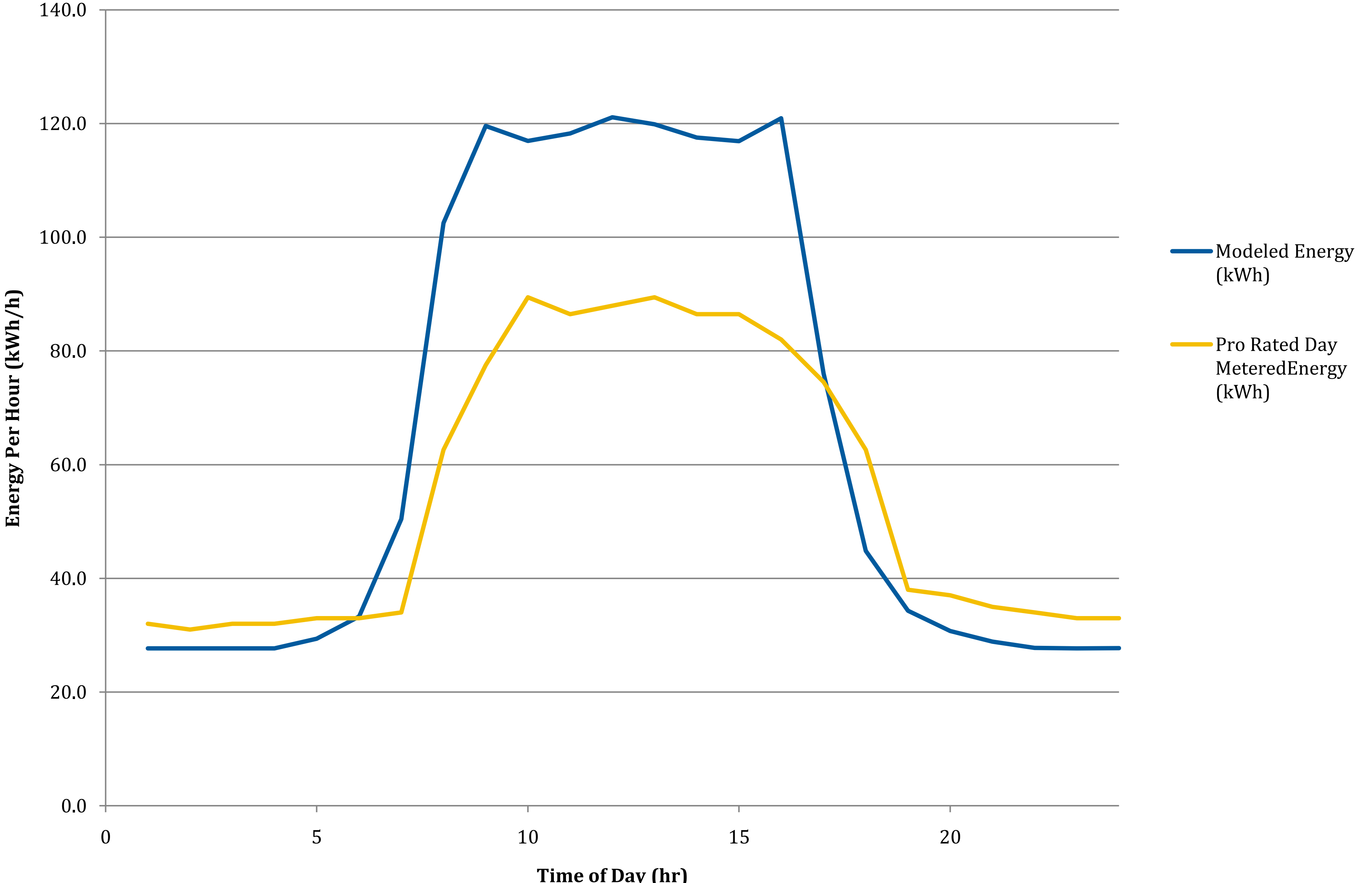
Computers
- Go from approximately 260 laptops, 33% of staff, to 720, 90% of staff, ensure standby mode works for all workstations

Data Center
• Blade Servers with Virtualization for 30% of nighttime load
•High efficiency UPS
•65W/employee current to 48W/employee in RSF

The result of the strategies is a 39% reduction in plug loads

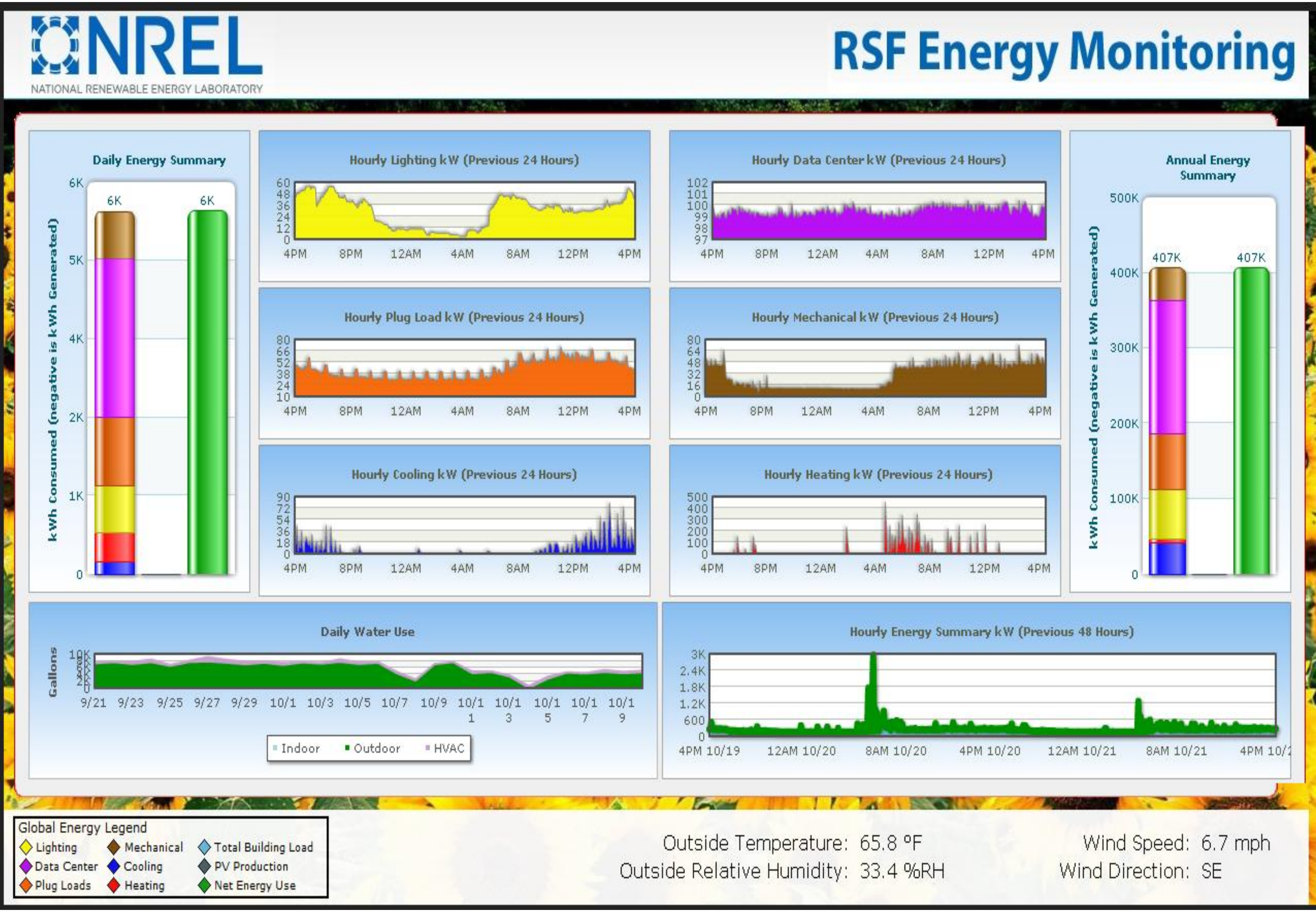


Pro Rated Day Time Plug Load Energy

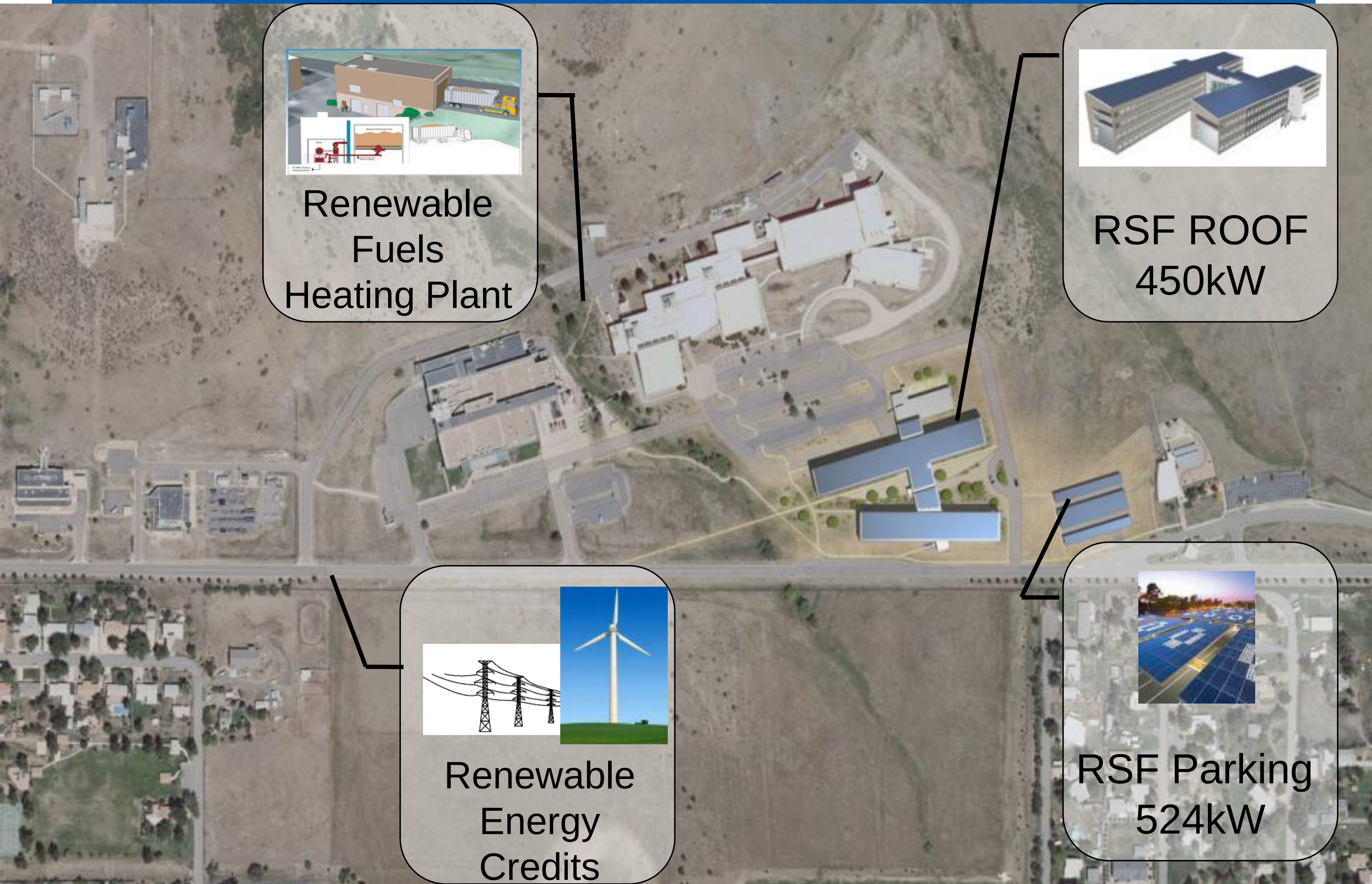


ZEB RENEWABLE HIERARCHY

- 0. Energy efficiency
    - Daylighting, CHP, passive solar
- 1. Footprint supply options
    - Building mounted PV or wind
- 2. Site supply options
    - Parking lot PV or wind
- 3. Imported supply options
    - Wood chips, ethanol
- 4. Purchase of renewable credits


NREL
NATIONAL RENEWABLE ENERGY LABORATORY
RSF Energy Monitoring
Daily Energy Summary
kWh Consumed (negative is kWh Generated)
6K
6K
Hourly Lighting kW (Previous 24 Hours)
Hourly Data Center kW (Previous 24 Hours)
Hourly Plug Load kW (Previous 24 Hours)
Hourly Mechanical kW (Previous 24 Hours)
Hourly Cooling kW (Previous 24 Hours)
Hourly Heating kW (Previous 24 Hours)
4PM 8PM 12AM 4AM 8AM 12PM 4PM
Annual Energy Summary
407K
407K
Daily Water Use
Gallons
Indoor
Outdoor
HVAC
Hourly Energy Summary kW (Previous 48 Hours)
4PM 10/19 12AM 10/20 8AM 10/20 4PM 10/20 12AM 10/21 8AM 10/21
Global Energy Legend
Lighting
Data Center
Plug Loads
Mechanical
Cooling
Heating
Total Building Load
PV Production
Net Energy Use
Outside Temperature: 65.8 °F
Outside Relative Humidity: 33.4 %RH
Wind Speed: 6.7 mph
Wind Direction: SE

RSF Renewables

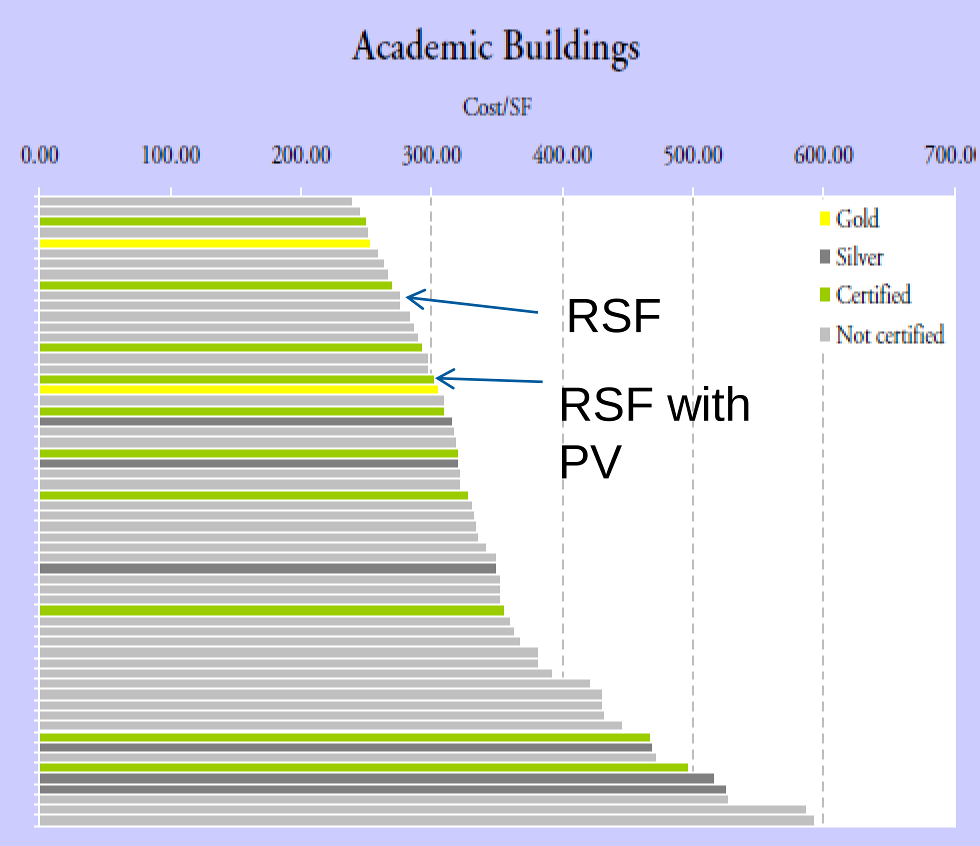


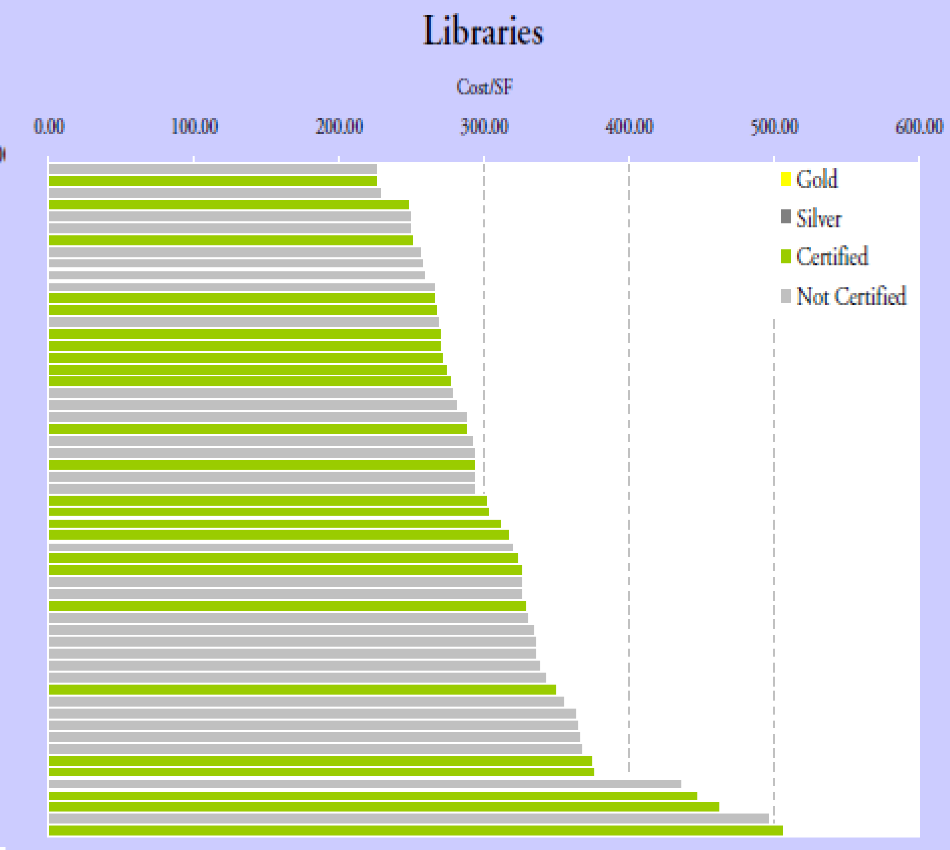
Davis Langdon LEED and Cost study

"Construction Costs normalized by location and time of construction"

http://www.davislangdon.com/upload/images/publications/USA/The%20Cost%20of%20Green%20Revisited.pdf

Cost of Green Revisited: Reexamining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption July 2007 |





A Local Comparison - EPA Region 8 Headquarters in Denver

- 67.4 kBtu/sf/yr 2008 measured EUI
- **Total Floorspace:** 301,292 ft^2
- **Year(s) EnergyStar Labeled (Rating):** 2008 (96)
  850 employees
- \$90 Million Building costs (\$298/ft^2), \$12.5 site costs
- 355 ft^2 / occupant ~ GSA typical occupant density

- Final RSF Occupant Density with 220,000 ft^2 and 822 occupants = 268 ft^2 / occupant (\$259/ft^2), 35 kBtu/sf/yr

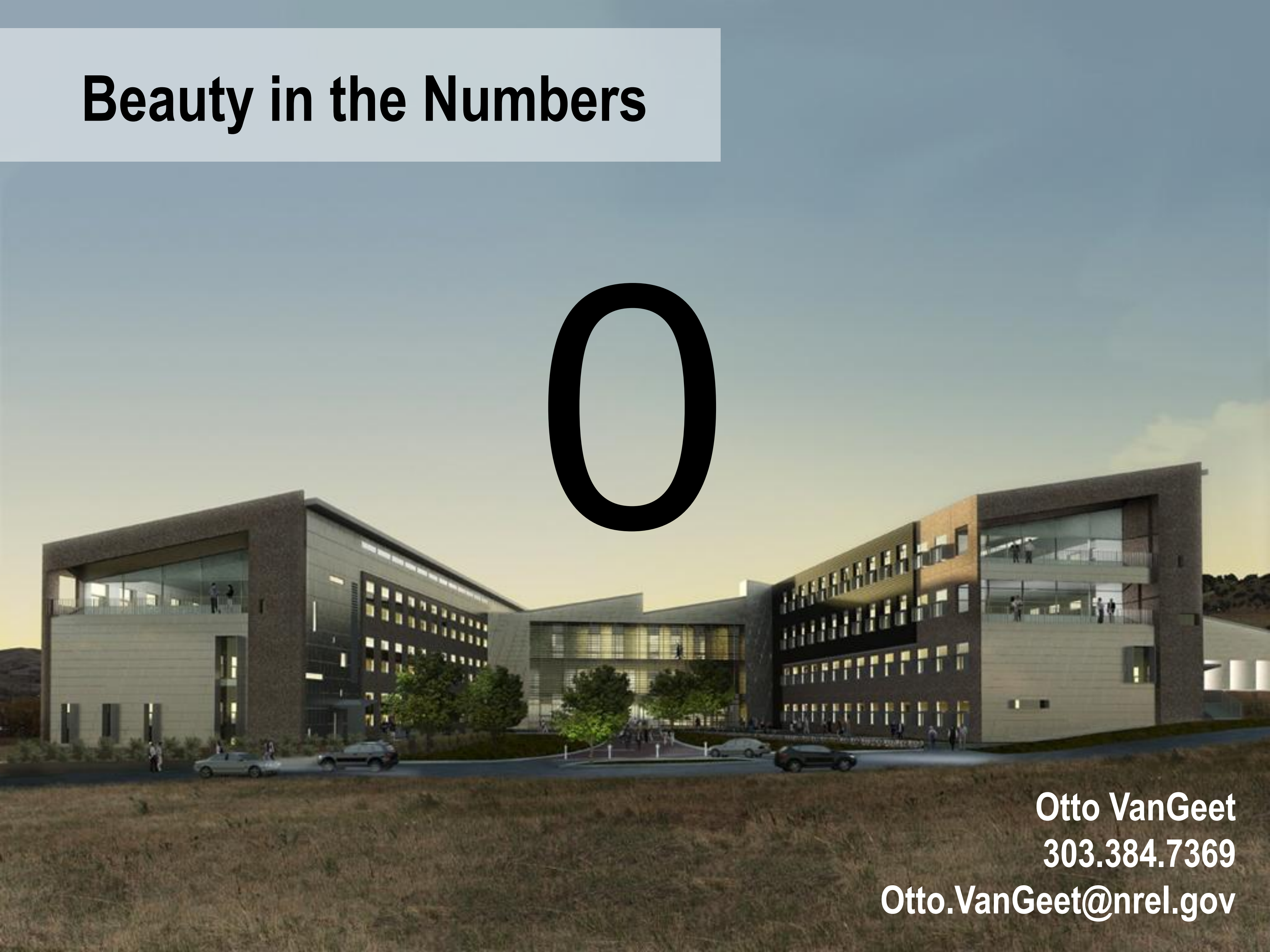
http://www.wbdg.org/references/cs_epadenver.php

http://www.energystar.gov/index.cfm?fuseaction=labeled_buildings.showProfile&profile_id=1006713

Ending Thoughts…

- Zero is Possible
- Zero takes a coordinated effort with the owner (and all user groups), architect, builder, and the engineering
- The little things make the difference in getting to zero
  - as you get to zero, little is significant- 1 watt saved = $33 of avoided PV costs
  - Thermal breaks
  - 2 W/phone – less with display switched off at night!
- The owner needs to set measurable contractual goals and communicate these goals to the design team
  - $ incentive helps too
- The solution is not bigger supplies
- How can we reduce plug loads?

Beauty in the Numbers



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